AP Chemistry - Important Scientists and their Contributions

Antoine Lavoisier	**Law of Conservation of Mass** Mass is neither created nor destroyed in a chemical reaction.
Joseph Proust	**Law of Definite Proportion** The same compound always contains exactly the same proportion of elements by mass.
Johann Doberiner	➢ Discovered a pattern of a group of elements like Cl, Br, and I (called triads).
John Newland	➢ Suggested elements should be arranged in "octaves" because they repeat their properties for every eight elements.
Dmitri Mendeleev	**Table of Elements** ➢ He was the first to conceive the modern Periodic Table of Elements. ➢ Insisted certain spots of the table be left blank until the actual element is found that matched the predicted properties. This was done to preserve the elements with similar properties called groups or families.
John Dalton	**Law of Multiple Proportion** When two elements form a series of compounds, the ratios of the masses of the second element that combine with the first element can always be reduced to small whole numbers. **Dalton Atomic Theory** 1. All elements are made up of tiny particles called atoms. 2. The atoms of a particular element are identical. Different elements have different kind of atoms. 3. Atoms cannot be created or destroyed. 4. Chemical compounds are formed when different kinds of atoms combine together. A particular compound always has the same relative numbers and types of atoms. 5. Chemical reactions deal with the rearrangement of the atom, which changes the way they are combined together. There is no change to the atoms themselves in a chemical reaction. **Dalton's Law of Partial Pressures** The total pressure exerted by a gaseous mixture is equal to the sum of partial pressures of each individual component in a gas mixture. ($P_{total} = P_A + P_B + P_C + \dots$)
J.J. Thomson	➢ measured the charge to mass ratio of an electron using a Cathode Ray Tube **Plum Pudding Model** Electrons are embedded in a cloud of protons.
Michael Faraday	➢ discovered a relationship between magnetism and rays of light (the electromagnetic properties of light) ➢ invented the Bunsen Burner ➢ invented the system of **Oxidation Number**. ➢ worked on Electrolysis, (Faraday Constant 9.65×10^4 C/mol – charge per mole of electrons)
Robert Milliken	**Milliken Oil Drop Experiment** Found the mass (9.11×10^{-31} kg) and the charge (1.6×10^{-19} C) of an electron when balancing the electric force and gravitational force of an electron across a set of charged plates.
James Chadwick	➢ Discovered neutrons
Ernest Rutherford	**Nuclear Model** He performed the famous ***Gold Foil Experiment*** and proposed that the protons and neutrons are in the centre of an atom (nucleus) where the electrons fly around the nucleus. The nucleus is very small and the atom is mainly made of empty space
Neil Bohr	**Bohr Atomic Model** Electrons are in specific orbits (energy level) around the nucleus, and therefore electrons are quantized. ➢ He helped developed the Quantum Mechanics Model (Electron Cloud Model), that is based on mathematical probabilities. ➢ Formulated the **Aufbau Principle**, which states the electrons fill orbitals starting at the lowest available energy states before filling higher states.
Max Planck	➢ He proposed the light could be viewed as particles as well as waves.
Albert Einstein	**Photoelectric Effect** He performed an experiment to which he proved that light could behave like particles (photons) – thereby proving Planck's hypothesis. These photons have kinetic energies, $E_k = hv_{min} - W$ (where Work function (W) = hv_{min} and Planck Constant (h) = 6.626×10^{-34} J s) Hence, we now accept the wave-particle duality of light (light can behaves like wave as well as particles). **Special Theory of Relativity** 1. Light travels at a constant speed in a vacuum ($c = 3.00 \times 10^8$ m/s) and hence time dilates and distance contracts when objects are near light speed. 2. $E = mc^2$

Louise de Broglie	**de Broglie Wavelength** ➢ Since light can behave like particles; particles can have wave properties. ($\lambda = \dfrac{h}{m\upsilon}$) ➢ Found uses in Electron Microscope.
Johannes Rydberg	➢ Developed the **Rydberg Equation** that explains spectral lines as electrons relax from higher to lower energy levels. $\left(\dfrac{1}{\lambda} = R_H\left(\dfrac{1}{n_i^2} - \dfrac{1}{n_f^2}\right)\right)$ from $E_n = \dfrac{R_H}{n^2}$ where $R_H = -2.178 \times 10^{-18}$ J
Theodore Lyman	➢ Worked on the ultraviolet spectrum of the hydrogen atoms to which the **Lyman Series** ($n_i \rightarrow n_1$) was named after.
Johann Balmer	➢ Studied and came up with the initial equation of the visible spectral lines of the hydrogen atom. The Balmer Series ($n_f \rightarrow n_2$) was named after his contributions.
Friedrich Paschen	➢ Worked on the infrared spectrum of the hydrogen atoms to which the **Paschen Series** ($n_i \rightarrow n_3$) was named after.
Frederick Brackett	➢ Studied the infrared radiation of the Sun, and thereby also worked on the infrared spectrum of the hydrogen atoms to which the **Brackett Series** ($n_i \rightarrow n_4$) was named after.
Wilhelm Röntgen	➢ Discovered X-ray.
Erwin Schrödinger	➢ Developed the Quantum Wave Equation that described the shape of the quantum subshells in an atom
Werner Heisenberg	➢ Credited as the creator of Quantum Mechanics. His Uncertainty Principle states that the simultaneous determination of two paired quantities, for example the position and momentum of a particle, has an unavoidable uncertainty.
Wolfgang Pauli	➢ Proposed the spin quantum number and formulated the Pauli Exclusion Principle, which states that no two electrons in a single atom can have the same quantum states (numbers).
Friedrich Hund	**Hund's Rule** For subshells that can have more than 1 orbital (as in $p, d, f,\ldots$), the lowest energy can be achieved when the electrons are arranged so that there are a **maximum number of unpaired electrons.** These unpaired electrons are drawn "spinning up" ($\uparrow$) in the orbital diagram.
Linus Pauling	➢ Studied energies needed to break dipole moments of molecules and developed the Electronegativity Scale of atoms. ➢ Explored the nature of ionic and covalent bondings. ➢ Introduced the concepts of orbital hybridizations (sp, sp^2, sp^3, dsp^3, and d^2sp^3). ➢ Pioneered the use of X-Ray Diffraction to study proteins and other biological molecules. ➢ Showed that smog was a product of automobile exhaust instead of factory exhaust. Pioneered the first electric car. ➢ Instrumental in pushing for a ban of above ground nuclear testing. He won both the Nobel Prize in Chemistry and Peace.
Gilbert Lewis	➢ Developed the famous **Lewis Dot Structures**. ➢ Laid the foundation of the concept of covalent bonding and odd electron molecules. ➢ Studied the magnetic properties of oxygen and nitrogen (paramagnetism and diamagnetism). ➢ Formulated an acid-base definition based on electron pairs. **Lewis Acids** are electron pair acceptors and **Lewis Bases** are electron pair donors. ➢ Lewis furthered the work of Gibbs by determining the Gibbs free energies of many substances using the relationship between Free Energy and Equilibrium Constant.
Evangelista Torricelli	➢ Invented the barometer using mercury. ➢ The very first pressure unit was named after (1 torr = 1 mm Hg and 760 torr = 760 mmHg = 1 atm)
Robert Boyle	➢ He studied the inverse relationship of *Pressure and Volume*.
Jacques Charles	➢ He studied the direct relationship of *Temperature and Volume*.
Joseph Gay-Lussac	➢ He studied the direct relationship of *Temperature and Pressure*. ➢ Discovered the water is two parts hydrogen and one part oxygen.
Amedeo Avogadro	➢ Developed **Avogadro's Law** which states that equal volumes of gases, at the same temperature and pressure, contain the same number of molecules. ➢ Distinguished the difference between molecules and atoms. ➢ Future scientists were able to use Avogadro's Law to find molar masses and atomic masses. ➢ The number 1 mole = 6.02×10^{23} was named after him. (Avogadro's Number $N_A = 6.02 \times 10^{23}$)
Thomas Graham	➢ Developed **Graham's Law of Effusion** which states that the rate of effusion of a gas is inversely proportional to the square root of its molar mass. $\left(\dfrac{r_1}{r_2} = \sqrt{\dfrac{M_2}{M_1}}\right)$

Rudolf Clausius and Benoît Clapeyron	➢ Together, they developed the relations between temperature and vapour pressure. By graphing the natural logarithm of vapour pressures (torr) against the reciprocals of various temperatures (K), we can determine the molar heat of vaporization. $$\ln(P_{vap}) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T}\right) + C \quad \text{or} \quad \ln\left(\frac{P_{vap,T_1}}{P_{vap,T_2}}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$ ➢ *Benoît Clapeyron* had first developed and stated the **Ideal Gas Law** ($PV = nRT$). ➢ *Rudolf Clausius* had first gave the mathematical version of the concept **Entropy**.
Fritz London	➢ Using Quantum Mechanics, and the idea of shifting electron densities, he developed an explanation for the intermolecular forces between non-polar molecules.
Johannes van der Waals	➢ Developed the theory of Intermolecular Forces, also called **van der Waals Forces**, which described the London Dispersion Force between non-polar molecules and Dipole-Dipole Forces between polar molecules. ➢ Formulate the **van der Waals Equation** to relate High Pressure, Volume and Low Temperature of a Real Gas by accounting for the volume of the molecules and their intermolecular forces. $$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$
William Henry	➢ Formulated **Henry's Law**, which states that the concentration of gas in a solution is directly proportional to the pressure above the solution. ($C = kP$ where k = Henry's Law Constant)
François-Marie Raoult	➢ Formulated **Raoult's Law**, which states that the vapour pressure of a solution is directly proportional to the mole fraction of the solvent. ($P_{soln} = \chi_{solvent} P^0_{solvent}$) ➢ He furthered developed the relationship of vapour pressure and the mole fraction of liquid-liquid ideal solution. ($P_{Total} = \chi_A P^0_A + \chi_B P^0_B$ where $\chi_A + \chi_B = 1$) ➢ Can be adapted to **Non-ideal Mixing** between non-polar and polar liquid-liquid solution with **Positive (Endothermic) Deviation** and **Negative (Exothermic) Deviation** to **Raoult's Law**
Jacobus van 't Hoff	➢ Developed the **van't Hoff Factor** that explains the colligative properties of electrolytic solutions. 1. Boiling Point Elevation: $\Delta T_b = iK_b \times \text{Molality}_{solute}$ 2. Freezing Point Depression: $\Delta T_f = iK_f \times \text{Molality}_{solute}$ vant't Hoff Factor (i) = $\dfrac{n_{ions}}{n_{solute}}$ 3. Osmotic Pressure: $\Pi = iCRT = \dfrac{nRT}{V}i$ **van't Hoff Equations** Relates Equilibrium Constants (K) with thermodynamic properties (enthalpy and entropy) $$\ln(K_P) = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R} \quad \text{or} \quad \ln\left(\frac{K_{P,T_1}}{K_{P,T_2}}\right) = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$
James Joule	➢ His work on heat and mechanical work lead to the development of the first law of thermodynamics – conservation of energy. ➢ The metric unit of energy is thus named after him (4.19 J = 1 cal)
Germain Hess	➢ Developed the concept of **Hess's Law** or **Hess Cycle**, which states the enthalpy changes are additive. In short, it can be summarized, $\Delta H_{rxn} = \Delta H_1 + \Delta H_2 + \Delta H_3 + \ldots$ or $\Delta H_{rxn} = \Delta H_{products} - \Delta H_{reactants}$
Josiah Willard Gibbs	➢ He was the first scientist to apply the second law of thermodynamics to relate between chemical, electrical, and thermal energy and capacity for external work. ➢ Developed the concept of **Gibbs Free Energy**, which is the amount of energy related to the entropy of the universe accounting for the dependency of a constant temperature. In short, it is the available energy after the account of enthalpy and entropy. ($\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$) ➢ Every system seeks to achieve a minimum of free energy. Hence the process is **thermodynamically spontaneous when $\Delta G^\circ < 0$**. ➢ Derivations relating Gibbs Free Energy with equilibrium are: $\Delta G = \Delta G^\circ + RT \ln(Q)$ and $\Delta G^\circ = -RT \ln(K)$ ➢ Derivations relating thermodynamics with electrochemistry are: $$\ln K = \frac{nFE^\circ_{cell}}{RT} \quad \text{or} \quad \log K = \frac{nE^\circ_{cell}}{0.0592\,\text{mol} \bullet \text{V}} \quad \text{(at 25°C)}$$

Svante Arrhenius	➢ Developed the relationship between Temperature and Rate Constant and thus can quantify Activation Energy. This is outlined in the **Arrhenius Equation**. $$k = A\, e^{\frac{-E_a}{RT}} \qquad \ln(k) = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln(A) \quad \text{or} \quad \ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$ ➢ Proposed an ionic theory of acids and bases. <u>**Arrhenius Acids**</u> are H^+ producers and <u>**Arrhenius Bases**</u> are OH^- producers.
Fritz Haber and Carl Bosch	➢ Developed a way to synthesize ammonia by using various catalysts.
Henry Le Châtelier	➢ Developed a quantitative method, <u>***Le Châtelier Principle***</u>, to predict the shift of equilibrium systems due to various stresses such as concentration, pressure, volume and temperature changes.
Johannes Nicolaus Brønsted and Thomas Lowry	➢ Formulate the concepts of <u>**Brønsted-Lowry Acids and Bases**</u>, where acids and bases are seen as reacting with water as they dissolved in the solvent. <u>**Brønsted-Lowry Acids**</u> are chemicals that donate proton, and <u>**Brønsted-Lowry Bases**</u> are chemicals that accepts proton.
Lawrence Henderson and Karl Hasselbalch	➢ While studying the carbonic acid buffer system in blood, they developed the <u>**Henderson-Hasselbalch Equation**</u>, which relates acid or base dissociation constants (K_a or K_b) with the pH of their particular buffer systems. $$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right) \quad \text{and} \quad pOH = pK_b + \log\left(\frac{[HB^+]}{[B]}\right)$$
Luigi Galvani and Alessandro Volta	➢ Separately developed the <u>**Electrochemical cells – Electric Batteries**</u>, commonly known as the galvanic cells or voltaic cells.
Walther Nernst	➢ Developed the Nernst Equation to predict the voltage of a concentration cells – an electrochemical cells where electrolytes are in different concentrations than the standard concentrations of 1.0 M. $$E_{\text{cell, conc}} = -\frac{RT}{nF}\ln Q \quad \text{or} \quad E_{\text{cell, conc}} = -\frac{0.0592\,\text{mol}\bullet\text{V}}{n}\log Q \quad Q = \frac{\left[A^{b+}_{(\text{low conc})}\right]^a}{\left[A^{b+}_{(\text{high conc})}\right]^a} = \frac{[\text{Anode Electrolyte}]}{[\text{Cathode Electrolyte}]}$$